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1. Your reference

GW-G33222

2. Patent application number
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0229544.2

18 DEC 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Shirin DEHGHAN
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RG14 6RS

Patents ADP number *(if you know it)*

78005 43001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

Wireless Communications Network Simulation Method

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

~~Bailey Walsh & Co~~
~~5 York Place~~
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Grove House
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Chineham Court
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224001

(AIL 29-1-04)

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| Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

| Number of earlier application | Date of filing *(day / month / year)* |
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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
*a) any applicant named in part 3 is not an inventor, or*
*b) there is an inventor who is not named as an applicant, or*
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| Priority documents | |
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| Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* | |
| Request for preliminary examination and search *(Patents Form 9/77)* | |
| Request for substantive examination *(Patents Form 10/77)* | |
| Any other documents *(please specify)* | |

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 17.12.2002

12. Name and daytime telephone number of person to contact in the United Kingdom

G Wood
0113 243 3824

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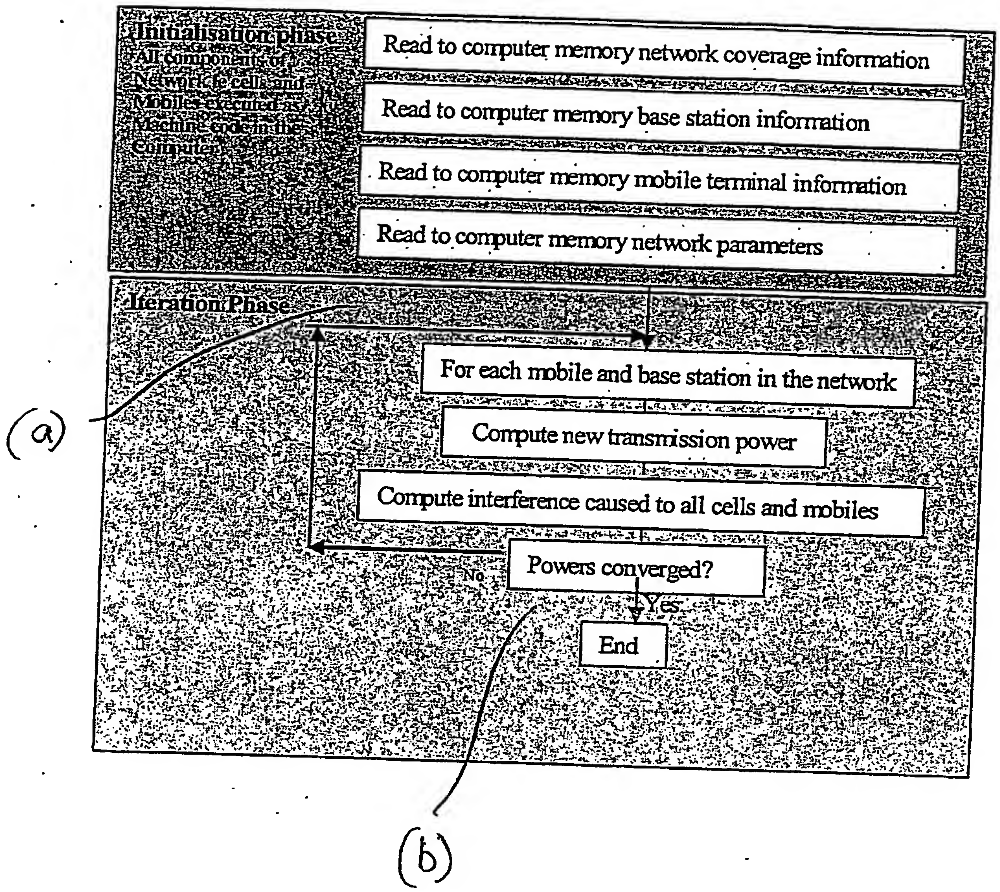


**Figure 1 CDMA power control convergence algorithm. The iteration phase can be prohibitively time-consuming.**

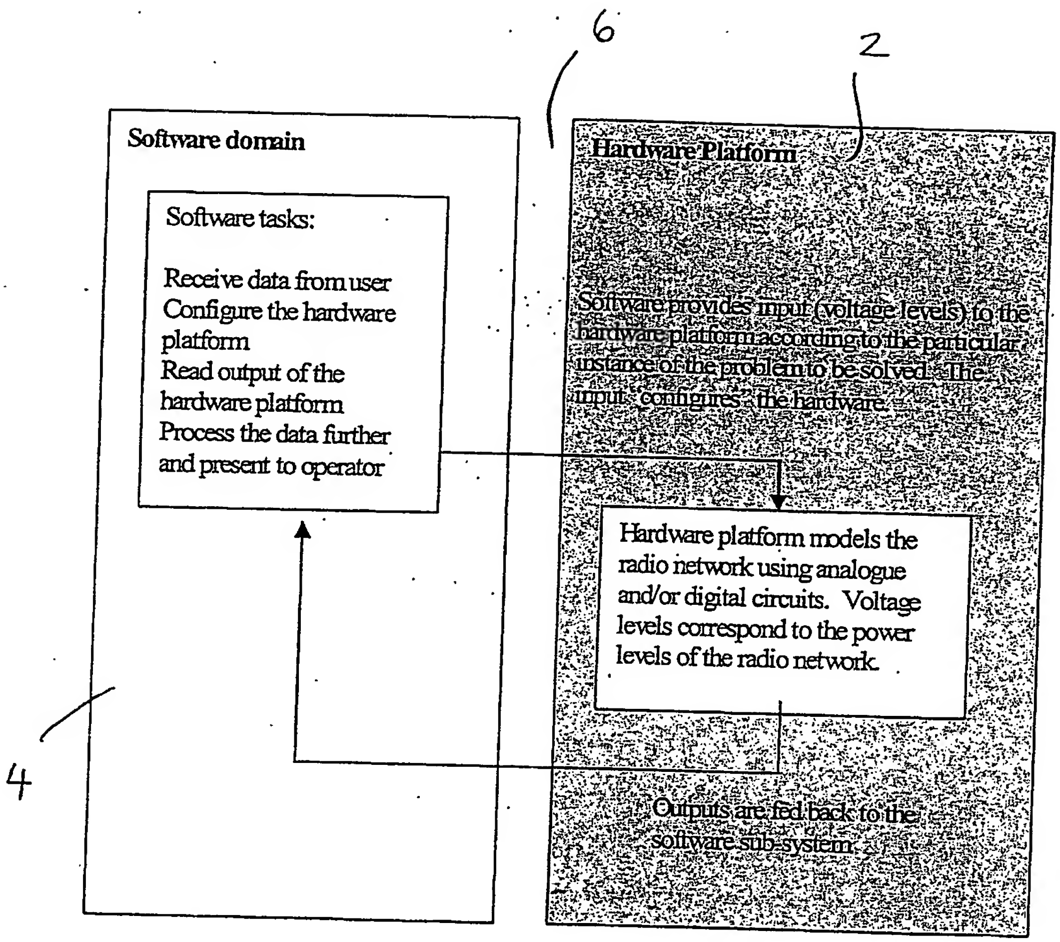


**Figure 2 Functional description of the hybrid software-hardware system.**

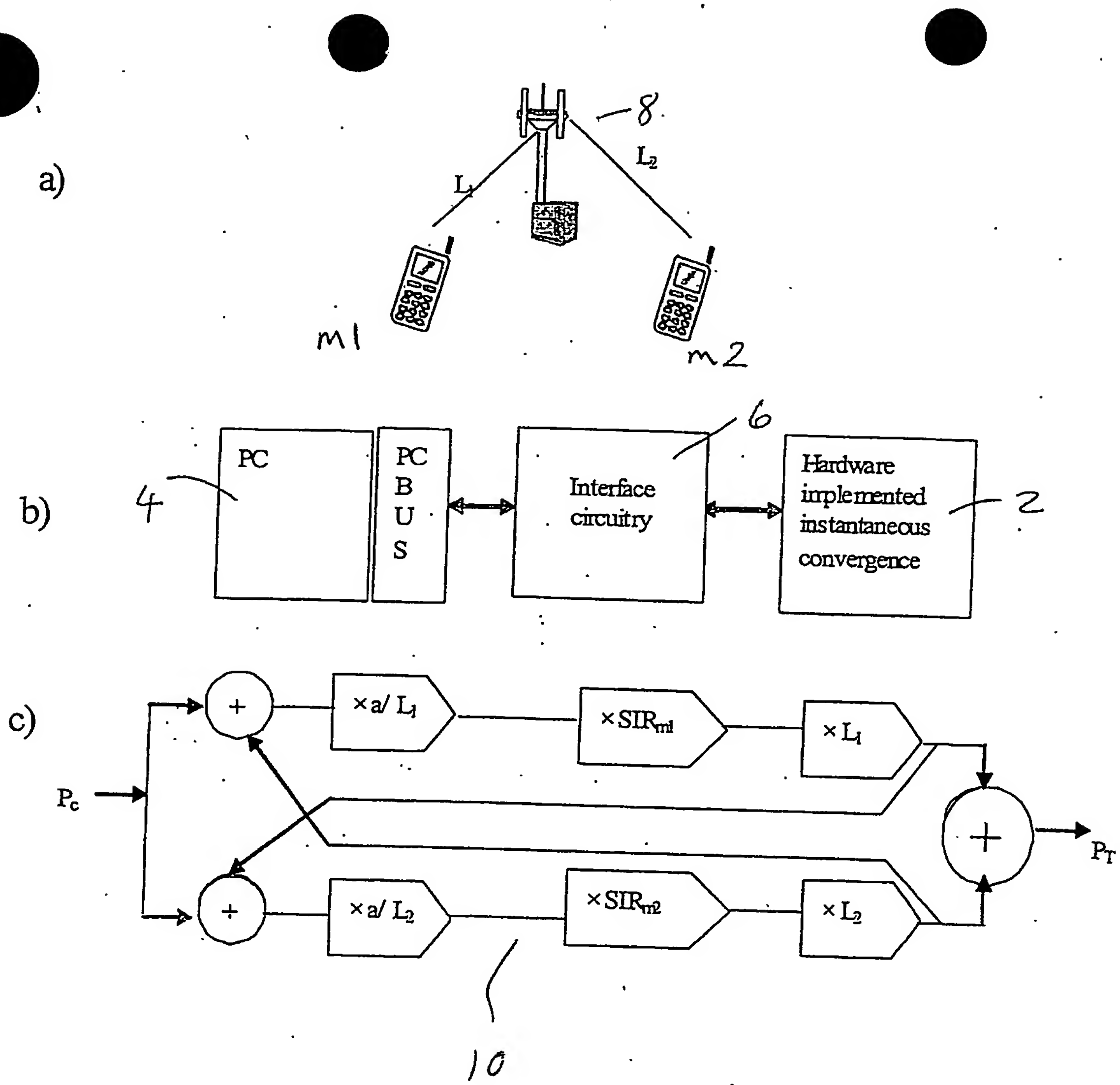


**Figure 3 Example implementation for a simple case**

a) **Depicts the configuration of one base station and two mobile terminals.**

b) **The block diagram of the system, where the computer system (PC) is interfaced to the hardware platform.**

c) **Detail of the implementation of the hardware platform to achieve instantaneous convergence.**

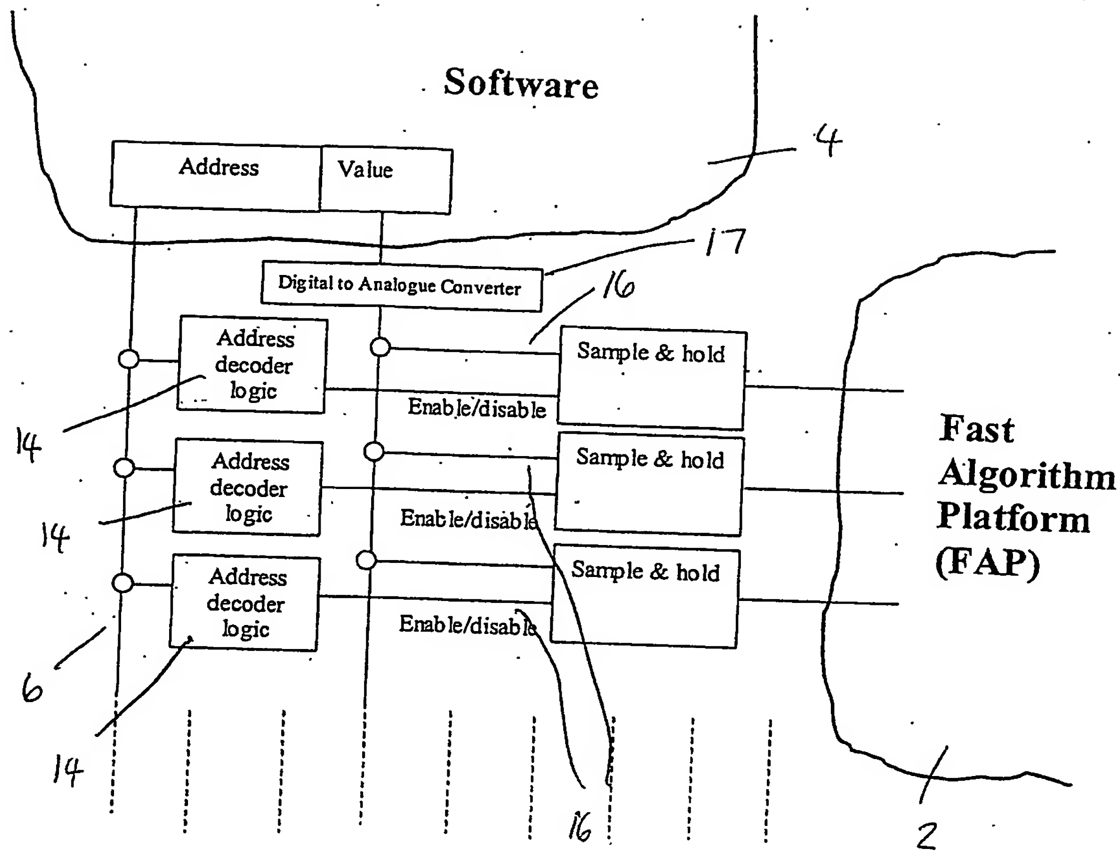


**Figure 4: Illustration of the interface required for configuring FAP under software control.**

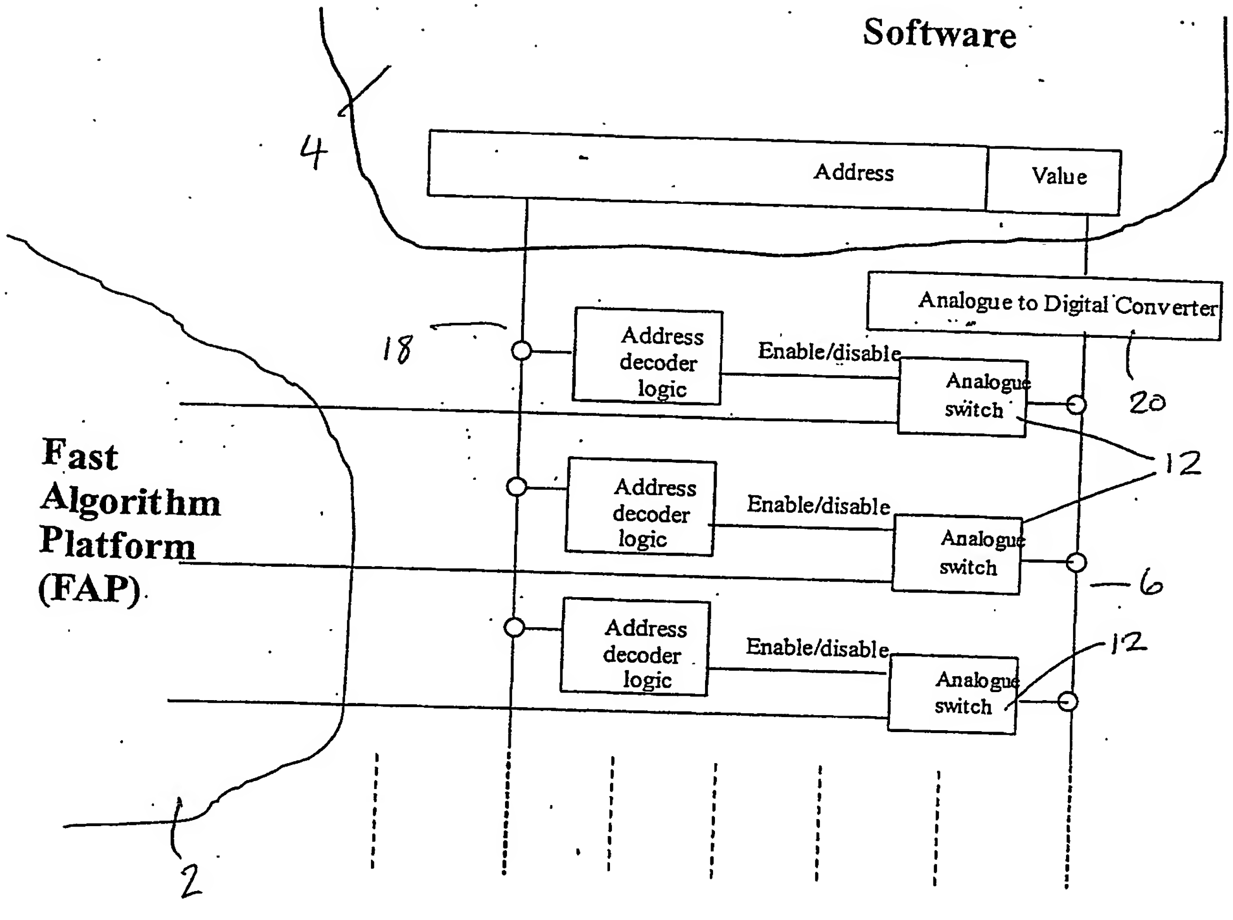


**Figure 5: Illustration of the interface required for reading the outputs of FAP into software.**

# Wireless Communications Network Simulation Method

The invention which is the subject of this application is a system and method which allows an improvement in the simulation stage of the development and design of a communications network in a wireless environment to be achieved and also, once designed, for that network to be further developed, amended and/or the performance optimised.

As is now well known, the use of communications networks for both business and personal use is widespread. As part of the development of these networks there is always pressure on the network provider to ensure that the network performs appropriately, to enhance the coverage area of the networks and also ensure that the networks can meet peak usage demand so that calls can be made by users when required. These networks are most commonly provided as and referred to as mobile phone networks and specific reference to the same will be made hereonin. However this should not be interpreted as limiting the scope of the invention which can be utilised in the development of any form of wireless communication system.

Generally, a communication network of the type to which the simulation in accordance with this invention relates, comprises a series of geographically spaced base stations which provide for the reception and transmission of digital, or analogue, communication signals. Signals can be transmitted to and received from handsets which are carried by the user and which can move with the user. Signals can also be transmitted and received to and from a network hub to the base stations. In order to provide a good geographical coverage which allows the signals to be transmitted to and received from the handsets at different geographical locations, a large number of parameters have to be determined such as the number of base stations, location of the base stations, power output of the stations, and so on.

As it is impractical to simply start constructing the network base stations and associated services in a real life situation there is the need to go through a planning procedure and arrive at a predetermined plan for the network. The procedure used is typically a two stage process. In the first stage the network designer selects base station locations in the geographical area to be served by the network and the antenna used in terms of type, height direction, power and the like. The second stage is a simulation stage in which, on the basis of the selections made at the manual stage, a software system is conventionally used to mimic or simulate the network operation and is to this simulation stage that the invention is directed. On the basis of the results of the first simulation, the manual stage is normally again entered to adjust parameter settings, for example, the height of one antenna, in order to improve the simulation results, the simulation stage is then again entered and so on for further parameter alterations. The simulation is designed to reach a set of parameter settings which allow the performance of the network to reach a predefined performance level prior to the installation.

The demands on the network provider can also be increased by the utilisation of specific network types. For example, Code-Division-Multiple-Access (CDMA) is the technique used for implementing the next generation (so called 3G) mobile communication systems. An inherent feature of CDMA is that all mobile network users have access to the whole frequency bandwidth all of the time. Thus a frequency reuse of one is a well-known feature of CDMA based systems. This means that the power emanated by the mobile terminals and the base stations must be tightly controlled. In order to design, plan, investigate and develop CDMA based systems; a software-based simulation of the network is carried out to ascertain the power levels at each base station and each mobile terminal.

Part of the simulation involves solving certain mathematical formulations for which there is no known "closed-form" solution. For this reason a numerical technique is employed whereby an initial solution is "guessed" and is iteratively modified until the true solution is obtained. In order to ascertain when the final solution is reached, a "convergence criterion" is defined, and the solution is then said to have "converged". The iterative algorithm used for power convergence in CDMA-based simulation applications written entirely in software is illustrated in the Figure 1 which illustrates the prior art procedure.

The number of "entities" for which a solution must be obtained is also large. For a 50km by 50km geographical area there can typically be 6000 base stations and 240,000 active mobile terminals. For reasons related to ensuring statistically accurate results, the problem must be solved repeatedly for different user location and/or activity status configurations (so called snapshots). The execution time required to converge to a solution for a network of this size for 50 snapshots can reach 25 hours. This is because a large number of iterations are required before the solution converges and the necessary computations at each iteration are time-consuming.

There are possibilities to increase the speed of such an algorithm using concurrent processing units, however the limiting factor in this case would be the overhead of communication between processors. In any case, the patent described here can also be applied to parallel processing implementations to further enhance the speed.

The known processes can therefore be extremely long and can consume large amounts of processing power as each change in parameter has to be passed through the iterative process. Thus, while the resultant network parameters which are achieved do result in an operative network in practice,

the process required to be undertaken to reach it is lengthy and due to this, and the lack of dynamism in the simulation process, subsequent amendment and development of the network tends to be resisted. It can also mean that due to the time of the development process the optimal design is not achieved but rather a network design which merely meets the network provider's minimum requirements.

The aim of the present invention is to provide an improvement to the known process by improving specifically the simulation stage of the process with the improvements in this stage providing an overall improvement in the process performance.

In a first aspect of the invention there is provided apparatus for modelling and simulation of wireless radio networks, comprising a configurable hardware platform that models the air interface and achieves rapid convergence (approaching real-time) to the state of the real network; a computer system that configures the said platform and carries out further analysis and presentation as required.

In one embodiment there is provided a method of investigating, analysing and designing mobile radio networks that employs the apparatus of the preceding paragraph.

In one embodiment the said network under consideration is classed as static, i.e. where mobile devices remain stationary as in a "time-freeze" analysis.

In an alternative embodiment the said network under consideration is classed as dynamic, i.e. where the position of mobiles varies as a function of time.

In one use the method is applied to the cellular radio network in real-time during network operation.

Typically the method is applied as part of a radio planning tool and utilised in the selection of radio base station site ,and/ or tune transmitter parameters and/or select antenna settings.

In one embodiment the method can be applied as part of a process that computes the optimum network configuration according to predefined criteria.

In one embodiment a hybrid software and hardware method is used to simulate, plan or optimise wireless radio networks.

In a further aspect of the invention there is provided a system for the design of a wireless communications network, said system comprising a first stage in which operator selected parameter settings for components of the network are determined and held, and a simulation stage into which certain operator defined parameters are input and wherein the simulation tool processes the input parameters utilising a hardware implementation of simulation of the air interface of the network to generate a set of data results.

The operator of the system may be a human operator or alternatively – as in the case of automatic computerised network planning systems and/or network optimisation systems – a computer that makes use of the system that is the subject of this invention.

Typically the set of data results can be compared to predefined network requirements and a decision reached as to whether they have been met and when met, the network parameters are deemed to be acceptable.

In one embodiment the air interface of the network is defined as the part of the network between the hardware of the handsets and the base stations. The simulation tool utilises a series of mathematical formula which are generated to mimic the air interface and, which can, as required, also refer to and utilise the parameter settings held in a database.

The data in the database can relate to any or any combination of the geographical area to be covered by the network, the number of handsets for which the simulation is to be generated, the status of the handsets i.e. whether moving or static, the power emissions from the handsets and/or base stations, settings of the base stations themselves, and in general any data which can be treated as a predetermined parameter which will not in practice change or change with little or no impact on the network performance.

The simulation tool can be used to generate data results on a real time basis As an example, if the network geographical area includes a heavily used transport link such as a motorway, commuter route or rail line, then the usage characteristics may vary largely during any given day as a result of rush hour traffic going in a first direction at the start of the day and the reverse direction at the end of the day with, in between those times, relatively less usage. Thus the database can hold data to allow the simulation of the use of the network at each of these different usage instances.

In a further aspect of the invention there is provided a simulation tool for the simulation of operation of part of a wireless communication network wherein said simulation relates to the air interface between the hardware components of the network.

In one embodiment, the hardware components are the handsets used by the users of the network on the first part and the base stations and antenna with which the same interact on the second part.

Typically the operator defined power levels in the simulation tool are represented by voltage signals at operator defined levels.

Preferably a series of implementations of the simulation method of the invention are performed to identify the set of data results which exceed the preset network design standard.

Thus in accordance with the invention the "state" and power levels of entities in a cellular radio network (base stations and mobile terminals) are simulated by applying voltages to a specially designed electronic circuits, causing currents to flow, and measuring the resulting potentials at the output of the circuit. The magnitude of applied voltages are chosen according to the specific configuration (i.e. control power levels, traffic distribution etc.) of the network being studied.

If desired, the magnitude of applied voltages can be varied to provide dynamism according to the specific instance (i.e. control power levels, traffic distribution etc.) of the network being studied and the output voltages are the resulting power levels of interest. The configuration of the circuit and further analysis, processing and presentation of the output are preferably carried out using a computer.

Thus, the need to compute the complex interdependence between the power levels of the base stations and the mobile terminals, in conjunction with the alteration of all other parameter settings and traffic distribution, by time consuming iterative algorithms is completely eliminated.

A specific embodiment of the invention is now described with reference to the accompanying drawings;

Figure 1 is a flow diagram outlining the conventional iterative algorithm used to reach power convergence as part of a code division multiple access (CDMA) based cellular system simulation implemented purely in software and executed within the computer processing unit;

Figure 2 is a diagram showing the interworking of an embodiment of the present invention and illustrating the software/hardware implementation;

Figure 3 illustrates a specific implementation of the present invention for a simple network comprising one base station and two handsets for illustrative purposes;

Figure 4 shows one embodiment of the interface circuitry required in order for the hardware platform to be configured under software control in accordance with the present invention; and

Figure 5 shows one embodiment of the interface circuitry required in order that the output of the hardware platform is sampled and read back into the software in the computer.

As the conventional simulation of a large number of base stations and handsets places a great deal of strain on the computational execution time of the simulation this limits the speed at which network designs and optimisation can be achieved by cellular operators using conventional systems. The technology is not specific to CDMA and is applicable to any wireless technology. In this section we use CDMA networks as a means to illustrate the invention and its benefits.

Simulating a CDMA network is primarily concerned with evaluating the powers transmitted by base stations and mobiles. In this system all mobiles communicate on the same frequency, F1, and all base stations communicate on the same frequency F2. Thus severe interference exists between these entities which are also dependent on their relative positions, which must be evaluated. In order to combat the interference, the correct levels of powers must be adopted by both the mobiles and base stations in order to achieve the predefined quality of service for the end user. The power required by

any mobile within the simulation problem may be evaluated using the following general equations.

$$P_{BS\_to\_m} = I_m \times \frac{(E_b / N_0)_m}{C / R_m} \times L_s$$

$$I_m = \sum_{n=1, n \neq s}^{Nbs} P_n \times \frac{1}{L_n} + (P_s - Pm) \times \frac{1}{L_s} \times a$$

where

$P_{BS\_to\_m}$ is the required power from the base station to mobile m

$E_b / N_0$ is the energy per bit over noise+interference spectral density, this parameter is crucial in ensuring an acceptable quality of service for mobile m

$C$ is the chip rate for CDMA systems

$R_m$ is the data rate for mobile m

$I_m$ represents the interference experienced by mobile m.

$L_s$ link loss from the serving base station of the mobile m

$P_n$ is the total power at other base stations where n=1 to Nbs which is the total number of base stations in the network being simulated where n does not equal s, which is the serving base station of mobile m

a is the non-orthogonality factor

The equation stated above has no known solution, as $P_{BS\_to\_m}$ depends on $I_m$ and $I_m$ itself depends on $P_{BS\_to\_m}$ as well as other base station powers.

This is also true when evaluating the powers for mobiles. The equations become:

$$P_{m\_to\_BS} = I_{BS} \times \frac{(E_b / N_0)_{m\_to\_BS}}{C / R_{m\_to\_BS}} \times L_s$$

where

$$I_m = \sum_{n=1,n\neq s}^{N_m} P_m \times \frac{1}{L_n} + (P_s - P_{m\_to\_BS}) \times \frac{1}{L_s}$$

In order to solve such equations, by using traditional methods, many iteration steps are required, where an initial solution (a) is guessed and modified at each step until the solution converges to the final value(s) (b) as shown in Figure 1 which illustrates the software implementation of such an algorithm. Such traditional iterative methods can take as long as 45 minutes to converge. If large areas of network are considered then this could easily be expected to increase to several hours. Operators currently have to use such slow methods to design cellular networks. This could potentially mean that a small area of say 5km by 5km could take (including iterations for design alterations) as long as five days to complete. Amplifying this to an area the size of UK, six years is required to design the entire UK with 30 engineers. The invention reduces this to 50 working days.

The invention offers a means of achieving instantaneous convergence by use of configurable hardware specially implemented to replace the most time consuming parts of the software simulators, which is the iterative convergence section.

In Figure 2 we illustrate the hybrid software (4) and hardware (2) system. In the example provided here, the (iterative) power control algorithm for all the cells and mobiles is to be implemented in hardware, 2. The resulting output is read back into software 4 for further analysis. The interface 6 between hardware and software is via analogue-to-digital and digital-to-analogue circuits in the case where the implementation of hardware is analogue and via memory-mapped circuits where the implementation of hardware is digital.

In Figures 3a-c an example implementation for simulating a simple network consisting of a single base station 8 and two mobiles m1, m2 is shown. It will be appreciated by the skilled person that the implementation is extendable to multiple base stations and mobile terminals. Furthermore, the downlink computations discussed here can be extended to the uplink case as well. Any other air interface parameters, such as radio resource management parameters can also be readily accommodated in the analysis.

The equations to evaluate the powers allocated to each mobile station, m1 and m2 by the base station (BS) 8 are as described in the following recursive equations:

$$P_{BS\_to\_m1} = I_{m1} \times \frac{(E_b / N_0)_{BS\_to\_m1}}{C / R_{BS\_to\_m1}} \times L_1$$

where

$$I_{m1} = (P_c + P_{BS\_to\_m2}) \times a \times \frac{1}{L_1}$$

and

$$P_{BS\_to\_m2} = I_{m2} \times \frac{(E_b / N_0)_{BS\_to\_m2}}{C / R_{BS\_to\_m2}} \times L_2$$

where

$$I_{m2} = (P_c + P_{BS\_to\_m1}) \times a \times \frac{1}{L_2}$$

and

$$\mathrm{SIR}_m = \frac{(E_b / N_0)_{BS\_to\_m}}{C / R_{BS\_to\_m}}$$

and total power is then:

$$P_T = P_{BS\_to\_m1} + P_{BS\_to\_m2} + P_c$$

where $P_c$ is the control channel power of the base station, and $P_T$ is the traffic channel power of the base station.

Figure 3c shows the components that make up the hardware configuration 10 for this simple example, comprising components that perform additions and multiplications. In the hardware platform the entity representing power in the radio network is voltage. Thus, for example, the control channel power of the base station, $P_c$, is represented by a voltage that is input to the hardware platform by the software. Similarly, the software configures the hardware platform by setting the other parameters L1, L2, and $\frac{(E_b / N_0)_{BS\_to\_m}}{C / R_{BS\_to\_m}}$. The output of the hardware, $P_T$, is read back by the software.

The extension to the full network can be described by the general equation presented above and the implementation presented in Figure 3a-c may be scaled to achieve instantaneous convergence.

It should be obvious to the skilled reader that this technique brings many benefits to the operators and reduces their design and optimisation time overheads significantly. As part of this process, optimisation techniques can also be applied to automate the whole process of RF design for cellular operators.

In summary, according to the present invention, the apparatus comprises a software-configurable hardware platform that models the air interface of a mobile radio network, achieves near-real-time simulation of the network and hence alleviates the need for and replaces time-consuming software

implementations currently in use. The invention (by itself or as an essential component of a larger system) has applications in modelling, analysis, design and optimisation of radio networks.

It will be appreciated by the skilled person that various other modifications and variations could be employed in relation to the embodiments described above, without departing from the scope of the present invention.

The configuration of the platform need not be static; by arranging for the configuration of the network to vary in time, according to a pre-programmed sequence of events stored in the computer, the time-varying dynamical nature of the network can be precisely studied. In this case, the operator defines a dynamic scenario by specifying the manner in which one or more parameter of the network changes with time. The sequence is stored in computer memory. When the operator initiates the analysis, for each time-step of the sequence, the specified configuration is translated to input voltages, applied to the hardware platform and the corresponding network state is read back and stored in the computer. The process is then repeated for each time-step. Hence a dynamic view of the network is built up corresponding to the dynamic scenario being studied.

Figure 4 shows the interface circuitry required in order for the hardware platform 2 to be configured under software control 4 via the interface 6. Here each "configuring parameter" is identified by a unique "address". The parameter will also have a corresponding "value" derived from the operator-specified network parameters. The digital value is converted to an analogue signal via a digital-to-analogue converter 17 and applied to the hardware platform via sample-and-hold circuitry. Routing of the converted signal is made possible by using address decoder logic 14 that enables the

corresponding sample-and-hold 16. Thus, each sample-and-hold is enabled for only one particular address and disabled otherwise.

Figure 5 shows the interface circuitry required in order that the output of the hardware platform 2 is sampled and read back into the computer .. Here the software 4 sets the "address" 18 of the hardware port that it wants to read, which in turn enables the corresponding analogue switch 12 that routes the relevant signal to an analogue-to-digital converter 20, the output of which is read as the value.

Figures 4 and 5 illustrate the case where data transfer between software and the hardware platform is carried out serially. This does not preclude a parallel data transfer configuration if deemed appropriate.

It is envisaged that "voltages" will be the most appropriate electrical property being used as configuring parameter and measured output parameter. This does not preclude using any other measurable electrical property, for example current, if deemed appropriate.